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A sensor package for mapping pH and oxygen from mobile platforms

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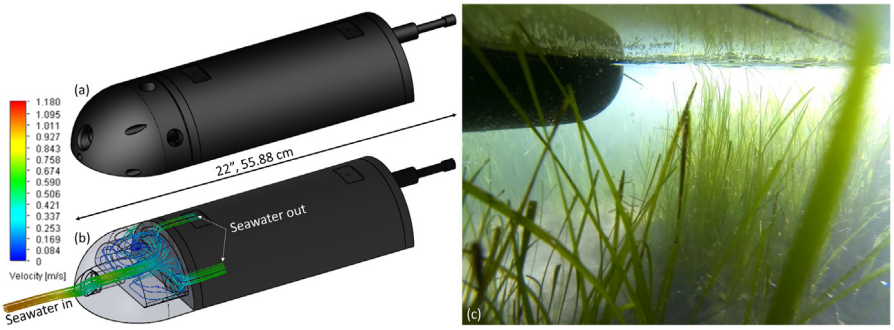
GRAPHICAL ABSTRACT



HIGHLIGHTS

- We designed a novel pH and oxygen sensor package specifically for mobile platforms.
- We mapped pH and dissolved oxygen in shallow, vegetated, hard-to-reach environments.
- The sensor performed very well (pH RMSE = 0.028) relative to discrete samples.
- 30 middle/high school students participated in supervised data collection/analysis.

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ABSTRACT

A novel chemical sensor package named "WavepHOx" was developed in order to facilitate measurement of surface ocean pH, dissolved oxygen, and temperature from mobile platforms. The system comprises a Honeywell Durafet pH sensor, Aanderaa optode oxygen sensor, and chloride ion selective electrode, packaged into a hydrodynamic, lightweight housing. The WavepHOx has been deployed on a stand-up paddleboard and a Liquid Robotics Wave Glider in multiple near-shore settings in the Southern California Bight. Integration of the WavepHOx into these mobile platforms has enabled high spatiotemporal resolution pH and dissolved oxygen data collection. It is a particularly valuable tool for mapping shallow, fragile, or densely vegetated ecosystems which cannot be easily accessed by other platforms. Results from three surveys in San Diego, California, are reported. We show pH and dissolved oxygen variability >0.3 and $>50\%$ saturation, respectively, over tens to hundreds of meters to highlight the degree of natural spatial variability in these vegetated ecosystems. When deployed during an extensive discrete sampling program, the WavepHOx pH had a root mean squared error of 0.028 relative to pH calculated from fifty six measurements of total alkalinity and dissolved inorganic carbon, confirming its capacity for accurate, high spatiotemporal resolution data collection.

1. Introduction

Coastal carbon budgets have proven particularly difficult to constrain due to their high levels of inter- and intra-ecosystem spatiotemporal heterogeneity (Borges, 2005; Borges et al., 2010, 2006; Chen and Borges, 2009; Gattuso et al., 1998; Laruelle et al., 2010). Current estimates suggest that continental shelves are a sink of 0.35 Pg C yr^{-1}, while inner estuaries, salt marshes, and mangroves forests are a source of 0.50 Pg C yr^{-1} (Cai, 2011). Nonetheless, uncertainty in continental shelf and coastal CO_2 fluxes remains quite large (between 50% and 75%) (Bauer et al., 2013) such that the magnitude and direction of coastal carbon fluxes are not well resolved over annual cycles (Hales et al., 2005). Despite these large uncertainties, it is still believed that coastal ecosystems are responsible for a disproportionately large percentage of global air–sea CO_2 flux, considering the fact that estuaries and continental shelves combined account for less than 10% of ocean surface area (Mackenzie et al., 2005). McLeod et al. (2011) suggested that a critical gap in our understanding of coastal carbon sequestration could be filled by mapping its spatial variability.

There is, therefore, substantial motivation to develop a tool specifically for marine inorganic carbon mapping applications. High resolution upper ocean carbon mapping is valuable in its own right as it has great potential to uncover meaningful biogeochemical patterns that could not be feasibly captured with observation programs limited to bottle sampling (Byrne et al., 2010). Furthermore, such techniques could also be used in a "prospecting" sense—that is, to determine optimal mooring sites prior to long-term static sensor deployments. There have been numerous attempts to characterize the temporal variability of inorganic carbon chemistry using moored autonomous sensors (Frieder et al., 2012; Gray et al., 2012, 2011; Harris et al., 2013; Hofmann et al., 2011; Kapsenberg et al., 2015; Martz et al., 2014, 2009; Price et al., 2012; Yu et al., 2011) and countless spatial surveys of upper ocean carbon dynamics (*e.g.*, Alin et al., 2012; Crosswell et al., 2012; Evans et al., 2013; Evans et al., 2012; Feely et al., 2001; Feely et al., 1998; Manzello et al., 2012; Rérolle et al., 2014; Takahashi et al., 2014; Takahashi et al., 2009; Zhang and Fischer, 2014; Zirino et al., 1986), but few tools exist to continuously